SECTION II.—GENERAL METEOROLOGY.

V. RAINFALL AND AGRICULTURE IN THE UNITED STATES.

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The agricultural year.

The purport of the accompanying Table 1 is to display the facts regarding the growing period of the various crops in relation to the work of the farmer. The subdivisions of the table are intended by their cross-classification to direct attention to the variety of the rainfall circumstances which accompany the growth of the separate crops.

(i) The cereal States occur in five rainfall regions.

(ii) The cotton States similarly spread over five regions. These form the two chief divisions of the table; so that the remainder of the country could be divided upon a rainfall basis as follows:

(iii) The northeast, chiefly region F.

(iv) The central east, the similar regions K and L.

(v) The west coast, region C.

(vi) The Mountain States, regions D and E.

Note should be made of the fact that where a State—e. g., Missouri—falls into two rainfall regions the whole State has been grouped with the more important part; this implies a defect, yet the general and broad results to which this investigation leads are, in all probability, but little vitiated by this circumstance.

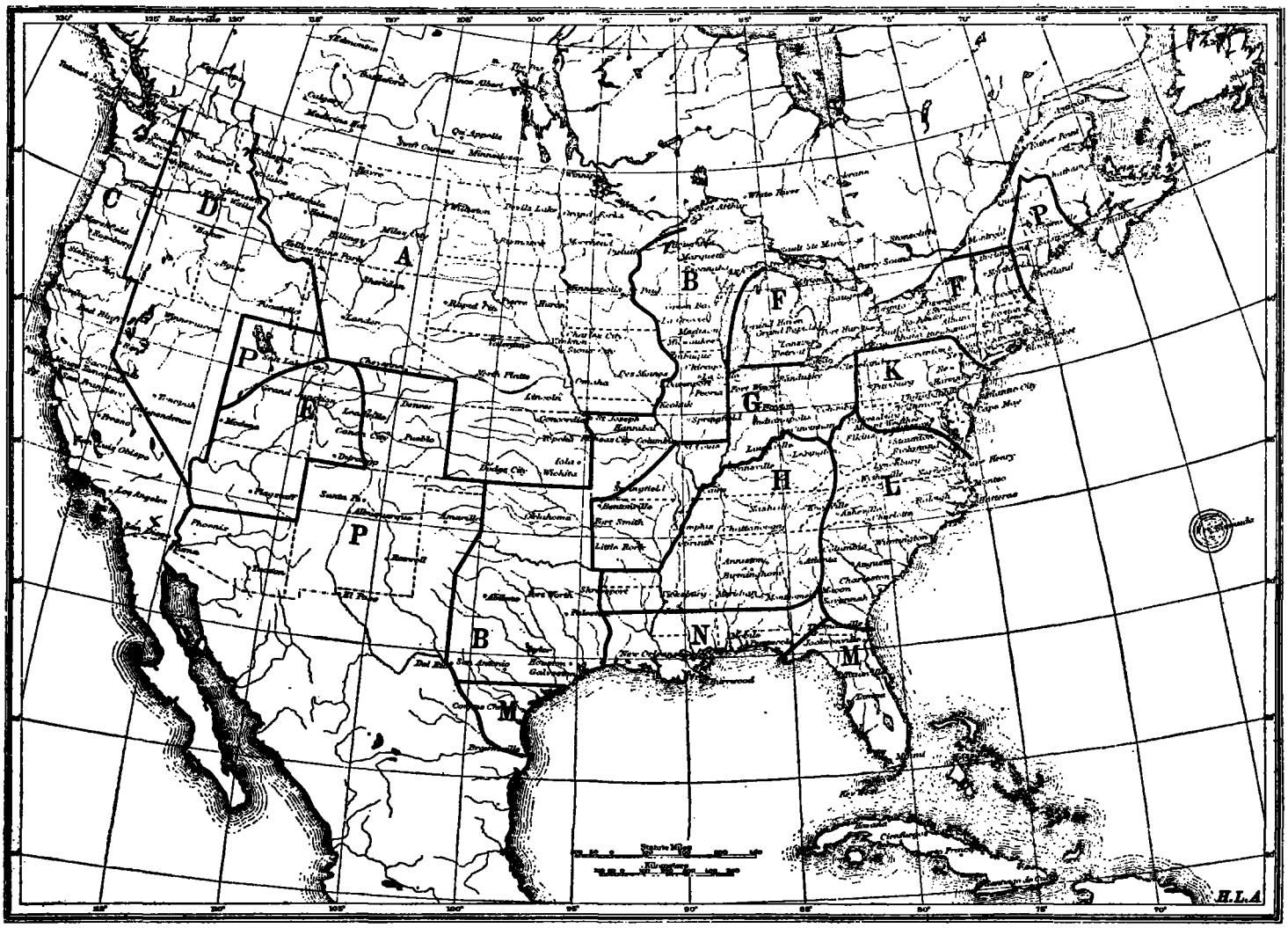

FIG. 43.—Approximate grouping of States as rainfall sections referred to in Table 1.

TABLE 1.—*The agricultural year in the United States.*[1]

	Beginning of sowing.	Beginning of reaping.	End of reaping.		Beginning of sowing.	Beginning of reaping.	End of reaping.
Wheat, winter,	A	a	a	Oats, fall,	F	f	f
Wheat, spring.	B	b	b	Oats, spring,	G	g	g
Rye, winter,	C	c	c	Maize,	H	h	h
Barley, fall,	D	d	d	Tobacco,	I	i	i
Barley, spring,	E	e	e	Cotton,	J	j	j

(i) THE CEREAL STATES.

States by sections. (See fig. 43.)	January.			February.			March.			April.			May.			June.			July.			August.			September.			October.			November.			December.		
	1–10	11–20	21–31	1–10	11–20	21–28	1–10	11–20	21–31	1–10	11–20	21–30	1–10	11–20	21–31	1–10	11–20	21–30	1–10	11–20	21–31	1–10	11–20	21–31	1–10	11–20	21–30	1–10	11–20	21–31	1–10	11–20	21–30	1–10	11–20	21–31
Section A.																																				
North Dakota										B		G	E	H	*						e	bg	e	bg	h	*	h								
Minnesota											BG		E*	H						ac	ac, e	bg	eg	b	A, Ch	*	h								
Montana														*							a		Aa		*										
South Dakota										BG	E		H	*						ac	ac, beg	e	bg	A	C		*		h				h		
Iowa									B	EG		*	H						ace	ac, bg	e	bg			AC			*	h				h		
Wyoming														*							a		A	a			*								
Nebraska									B	EG			H*						ac	ac, beg	e	bg			AC		h*							h		
Kansas						B	G	E			H	*						ace	cg	aeg, b	b				C	A			h*					h		
Section B (north).																																				
Wisconsin										B	G	E		H	*	I				ac	ac, be	ge	ibg		Ah	C	h*								
Illinois								G	B			H*			I			ac	gac	b	bg			i	C	A	hl		*				h		
Missouri							G	E			H*				I		ac		eg, ac	eg				i	AC		hl		*					h	
Section F.																																				
Michigan										G		BE		H*						ac	eac	bg	e	bg	A C, h		h	*								
Section G.																																				
Indiana								G	E				H*		I		d	acd	eac	ge	g			i	A C, D		hl			*				h		
Ohio									EG				H*		I			ad	ced	gac	e	g	i		CD	Ah	i	h*								
Section H.																																				
Kentucky							G				H	*		I			acd	d	gac		g			i	CD	Ah	i		*			h				

(ii) THE COTTON STATES.

Section B (south)																																					
Oklahoma				G	E			H		J		*				c	aeg		ac, eg						C	A hj		*					h		j
Texas			BG		H			J				*			afd	c	b f	ac	g b	d	g			j	h	C	A D	F	*			h		j		
Section H.																																					
Tennessee				G		G			H		*	J	I			a		g a		g				i	j		A hl	*					j	h		
Mississippi				G				H	*	J					f	fg	f	g						j			h	F		*		h		j		
Alabama			G					H		J	*				f	ag	f	ag						j		h		A F	*					hj		
Georgia				G				H		J	*				cf	a	g c	af	g					j		C h		F	A *			h		j		
Arkansas				G			H			J	*		I			a	g	a	g					i	j		A hl			*	h		j			
Section L.																																					
North Carolina						G			H		J*	I				f	acg	af	cg					i			Cj l		F h		A *			h	j		
South Carolina			B					H		IJ	*				cf	b	a c	abf		i				l	j		h	C	F	A	*			j	h		
Section M.																																					
Florida						H		J	I		*		f			f	i					l	j	h					F h		*		j				
Section N.																																					
Louisiana						H			J*						f		f							j	h				F		h *				j		

(iii) THE NORTHEASTERN STATES.

Section F.																																					
New York										G	B	E		H*		I			a	c	beg, ac	i	be	g	A C, hl		h	*								
Connecticut										G			H*		I				c	g	i c	g			Ch	i	h	*								
Vermont											G	B		E, H*							ac	A, beg, c	a	C, be	h g		h*									
New Hampshire													G	E, H*								eg		e	h g	*	h									
Rhode Island										G	*		H				c			c	g	g		C	h		h		*							
Massachusetts										G			H*	E	I					ei c	g	e	C		hl		h	*								
Areas P.																																					
Maine													G	E, H*									eg		eg	h	h*									

[1] This table is based upon the results of an inquiry into dates of farm operations as published in the Yearbook of the Department of Agriculture, U. S. A., 1910, pp. 489–493, and as kindly supplied for some western States by the Department of Agriculture.

* Limits of average period free from killing frosts.

TABLE 1.—*The agricultural year*—Concluded.

(iv) THE CENTRAL EASTERN STATES.

States by sections. (See Fig. 43.)	January.			February.			March.			April.			May.			June.			July.			August.			September.			October.			November.			December.		
	1–10	11–20	21–31	1–10	11–20	21–28	1–10	11–20	21–31	1–10	11–20	21–30	1–10	11–21	21–31	1–10	11–20	21–30	1–10	11–20	21–31	1–10	11–20	21–31	1–10	11–20	21–30	1–10	11–20	21–31	1–10	11–20	21–30	1–10	11–20	21–31
Section K.																																				
Pennsylvania										B E G			H*		I				ac	b ac	cg	e	i g		A	Ch i		h	*							
New Jersey										G			H*					c	a	g ac		g			C	A	h		*		h					
Maryland								G				H*			I			ac	ac	g	g		i		h	A C	hi			*						
Delaware												H*						a a						h			h	A		*						
Section L.																																				
West Virginia									G			H*			I			ac	a	g c	g			i	h	A C	i	h	*							
Virginia								G				H*			I			a	c	g ac		g			i	A C h	i			*		h				

(v) THE WEST COAST STATES.

Section C.																																				
Washington															*						a			a	A					*						
Oregon															*						a			a		A	*									
California [2]																																				
Idaho [2]																																				
New Mexico [2]																																				

(vi) THE MOUNTAIN STATES.

Section D.																																				
Nevada															*				a			a			A	*									
Section E.																																				
Utah													*							a		a			A			*								
Colorado													*								a	a	A						*							
Arizona										*						a		a										A			---	*				

* Limits of average period free from killing frosts.

[2] No data available.

The main importance of Table 1 lies in its demonstration (1) of the concentration of the farmer's effort at two periods of the year, and (2) of the variety in the date of the summer period between the completion of the first sowings and the commencement of the harvest.

The blanks in the early parts of the year signalize the absence of field work, but the blank space which occurs down the summer and autumn months lacks this significance.

The summer sowings are, however, completed by June 10, except in the case of tobacco, which is planted until the end of the month. With the exception of winter wheat in South Carolina, which is sown up to December 8, the winter and autumn sowings are completed by the end of November and in most cases by the end of October.

As a general rule the sequence of crops as sown tends to be consistent throughout the country.

Certain important facts emerge from the table in relation to the rainfall régime of the areas.

I. The wettest month is usually avoided for harvesting operations; generally the harvest is taken in the period following the rainfall maximum. The rainfall maximum of sections G and H falls early so that harvesting may begin in June. In the central Eastern States, however the harvest tends to be completed before the rainfall maximum occurs. This circumstance is strikingly illustrated in the cotton States, where the cereal harvests are gathered before the heavy rains and the maize and cotton crops after the maximum has passed.

II. Generally the summer crops are sown almost immediately before the rains commence and the winter and fall crops immediately the heaviest rains are over; the fast-growing crops are well watered at once and the slow-growing seeds lie during a long period which is dry and cold.

III. The variations in the dates of spring sowings are governed by the dates on which the last killing frosts of spring fall due; this is remarkably shown in connection with the sowing of maize (Indian corn). It becomes, therefore, obvious that, while sowing is related to frost as well as to rainfall, there is a definite adjustment of harvesting operations to the rainfall conditions.

Rainfall during the growing period.

Table 2 is based upon Table 1 and is designed to demonstrate the adjustment of the growing period to the variations in precipitation which occur. The rainfall values are based upon the pluviometric coefficients set out in Part II (this REVIEW, January, 1915, p. 14, ffg.). It might be suggested that these rainfall values would have been more easily obtained by averaging the actual rainfall values which are published in the rainfall statistics issued by the Weather Bureau. Such a suggestion, however, is open to a definite objection. It has been admitted that the method of pluviometric coefficients provides a better knowledge of average monthly rainfall values on the ground that it smooths out the effect of accidental rain splashes; and the addition to the pluviometric coefficients of the generalized equipluves tends still further to provide a more accurate statement of the rainfall régime of the country. Consequently the extra labor involved in the calculations is well worth while.

TABLE 2.—*The total precipitation during the growing period of the crops.*

States.	Winter crops.				Fall crops.				Spring crops.											
	Wheat (*A*).		Rye (*C*).		Barley (*D*).		Oats (*F*).		Wheat (*B*).		Barley (*E*).		Oats (*G*).		Maize (*H*).		Tobacco (*I*).		Cotton (*J*).	
	Growing period.	Rainfall during growth.	Growing period.	Rainfall during growth.	Growing period.	Rainfall during growth.	Growing period.	Rainfall during growth.	Growing period.	Rainfall during growth.	Growing period.	Rainfall during growth.	Growing period.	Rainfall during growth.	Growing period.	Rainfall during growth.	Growing period.	Rainfall during growth.	Growing period.	Rainfall during growth.
	Mo.	*Inches.*	*Mo.*	*Inches.*	*Mo.*	*Inches.*	*Mo.*	*Inches.*	*Mo.*	*Inches.*	*Mo.*	*Inches.*	*Mo.*	*Inches.*	*Mo.*	*Inches.*	*Mo.*	*Inches.*	*Mo.*	*Inches.*
(i) The Cereal States.																				
North Dakota									4	10	2⅝	7	3½	9	3⅔	10				
Minnesota	10½	22	10⅓	22					3⅝	14	2⅝	10	3½	14	3⅝	14				
Montana	11½	13																		
South Dakota	10⅝	18	10½	17					3⅝	11	3½	9	3⅝	11	5½	14				
Iowa	10	24	10	24					3⅝	14	3	11	3½	13	5⅓	17				
Wyoming	11⅓	12																		
Nebraska	10	20	10	20					3⅔	13	3⅛	12	3⅛	12	4⅝	17				
Kansas	9½	22	9⅔	23					4⅛	15	3½	10	4	13	6	20				
Wisconsin	10½	25	10	24					3⅝	13	3	11	3⅝	13	3⅝	14	2½	9		
Illinois	9½	27	9⅔	28					3⅝	14			3½	14	5	18	3	11		
Missouri	9½	27	9½	27							3⅝	16	4	13	5½	22	3	12		
Michigan	10½	26	10½	26					3½	10	3	10	4	11	3⅝	11				
Indiana	9⅔	32	9⅔	32	9½	30					3⅝	14	4	15	4⅔	17	3	11		
Ohio	9½	27	10	30	9⅔	28					3⅝	13	3⅔	14	4⅓	16	2⅔	11		
Kentucky	9	35	9½	36	9½	35							4	17	5	19	3½	13		
(ii) The Cotton States.																				
Oklahoma	9	24	9	23							1	12	4	16	5⅔	22			5	19
Texas	8	18	8⅝	20	9⅔	27	7⅔	18	4⅝	11			5½	11	6⅔	18			5	17
Tennessee	8½	22											4	12	6	24	3½	13	4½	17
Mississippi							8	27					4	19	6⅔	29			4⅔	20
Alabama	8	32					7⅔	32					4½	20	6	26			4⅔	19
Georgia	7⅔	30	8⅓	33			7⅔	30					4⅓	18	6	28			4⅔	21
Arkansas	8⅔	32											4	19	6⅓	29	3	14	4⅔	19
North Carolina	8	30	9⅓	36			8⅓	30					3⅔	15	6	28	3½	15	4⅔	20
South Carolina	8½	30	8	27			7⅔	27	4⅓	20					6	26	3½	15	4⅔	19
Florida							6⅔	24							6	28	2⅔	11	5	23
Louisiana							7⅓	33							6⅓	27			5	22
(iii) The Northeastern States.																				
New York	10	30	10⅓	32					3⅓	12	3	12	3⅔	13	3⅔	15	2	9		
Connecticut			10	38									3½	12	4	16	2	8		
Vermont	11⅔	37	11	31					3⅓	12	2⅔	10	3⅔	13	3⅔	14				
New Hampshire											2⅔	10	3	11	3⅔	14				
Rhode Island			9⅓	38									4	11	4½	15				
Massachusetts			11	38							2⅓	8	3½	11	4⅓	14	2	7		
Maine											3	10	3½	11	4	14				
(iv) The Central Eastern States.																				
Pennsylvania	10	31	9⅔	30					3⅓	13	3⅔	14	3⅔	14	4⅓	17	2⅓	10		
New Jersey	9⅔	37	9⅔	37									3½	13	4⅔	19				
Maryland	7⅓	26	7⅓	26									4	15	4⅓	18	2⅔	11		
Delaware	8⅔	29													4	15				
West Virginia	9⅓	32	9½	32									3⅔	15	4⅓	18	3	13		
Virginia	9	31	9⅓	32									3⅔	14	5	21	3⅓	15		
(v) The West Coast States.																				
Washington	10⅔	32																		
Oregon	10⅓	29																		
(vi) The Mountain States.																				
Nevada	9⅔	7																		
Utah	10½	12																		
Colorado	11	14																		
Arizona	8	14																		

In connection with the rainfall values it should be noted that the average total annual precipitation of the States varies from 10 to 50 inches, so that within this very large range it is an important fact to note that the agriculturist—no matter how extensive or how small the scale of his operations may be—tends to make a definite adjustment of his growing period in order to arrange for a definite total rainfall during the period of growth of each crop.

This adjustment becomes noticeable from a consideration of the following summary:

Summary showing limits of precipitation and rainfall in Table 2.

Crops.	Key letter.	Growing periods.		Precipitation.	
		Shortest.	Longest.	Least.	Greatest.
		Months.	*Months.*	*Inches.*	*Inches.*
Winter wheat	(*A*)	7⅔	11⅔	7	37
Winter rye	(*C*)	7⅓	11	17	37
Fall barley	(*D*)	9½	9⅔	27	35

Summary showing limits of precipitation and rainfall in Table 2—Con.

Crops.	Key letter.	Growing periods.		Precipitation.	
		Shortest.	Longest.	Least.	Greatest.
		Months.	*Months.*	*Inches.*	*Inches.*
Fall oats	(*F*)	6⅔	8½	18	33
Spring wheat	(*B*)	3½	4⅔	10	20
Spring barley	(*E*)	2⅔	4	7	16
Spring oats	(*G*)	3⅔	5½	9	22
Spring maize	(*H*)	3⅔	6⅓	10	29
Tobacco	(*I*)	2	3¾	7	15
Cotton	(*J*)	4½	5	17	23

The range of variation shown above is, however, fairly wide and it is imperative to investigate the quality of each State as a crop producer before attempting to arrive at any more definite conclusions.

Relative agricultural produce.

Table 3 aims at the provision of material for the investigation of the relative merits of the several States in regard to crops.

The values in columns (*a*) and (*e*) of Table 3 form a kind of index numbers which indicate relative values of the crop; a high number signifies a combination of a large proportion of the area of the State devoted to this particular crop, with a high average yield per acre. The relative yield per acre is shown in columns (*b*), (*f*), and (*g*), and columns (*c*) and (*d*) show the proportion of the United States acreage given to the crop in 1910 and 1900, respectively. A State which has high values in all col-

TABLE 3.—*Relative agricultural produce.*

States.	Wheat.				Rye.				Barley.				Oats.				Maize.				Tobacco.			Cotton.			
	(*a*)	(*b*)	(*c*)	(*d*)	(*a*)	(*b*)	(*c*)	(*d*)	(*a*)	(*b*)	(*c*)	(*d*)	(*a*)	(*b*)	(*c*)	(*d*)	(*a*)	(*b*)	(*c*)	(*d*)	(*e*)	(*f*)	(*c*)	(*c*)	(*g*)	(*c*)	(*d*)
(i) The Cereal States.																											
North Dakota	935	10	145	63	2	12	7	10	230	15	136	84	485	21	46	22	51	23	2								
Minnesota	768	15	119	115	24	19	57	33	383	23	178	112	772	28	78	61	562	32	15	11							
Montana	25	25	10	2	1	23			4	34	7	2	68	43	10	2											
South Dakota	475	13	74	69	8	18	17	2	285	22	142	37	465	26	43	21	705	28	19	14							
Iowa	145	18	11	33	11	19	16	63	252	26	71	153	2,100	30	136	122	5,400	33	83	96							
Wyoming	12	26	2						1	32	1		24	34	4	1											
Nebraska	601	17	50	49	16	16	37	38	36	22	19	11	760	25	75	63	2,680	26	70	97							
Kansas	899	14	90	110	3	14	19	79	68	17	41	67	250	28	40	50	2,000	20	78	102							
Wisconsin	64	19	4	19	88	17	150	120	380	28	119	85	1,260	32	66	71	910	33	14	15	34	10	24				
Illinois	625	15	42	32	20	17	35	46	15	29	4	4	1,740	32	130	128	5,680	35	93	85	1	7	1				
Missouri	390	13	37	35	3	14	7	6					300	27	22	33	3,150	29	73	77							
Michigan	235	17	18	29	93	16	173	45	30	26	9	13	650	29	43	34	970	33	18	13							
Indiana	1,140	16	53	28	24	16	17	20	6	25	1	2	1,100	29	53	50	4,400	36	45	48	15	8	22				
Ohio	850	19	39	34	23	17	28	19	18	27	4	8	975	32	50	39	3,150	38	35	35	62	8	75				
Kentucky	333	12	15	22	4	13	6	14					85	21	5	16	2,270	28	32	32	250	7	383				
		16	709	640		17	569	495		25	732	578		29	801	713		30	577	625		8	504				
(ii) The Cotton States.																											
Oklahoma	212	13	32	33	1	14	2		9	25	4		171	27	18		1,790	19	51	6				3	163	68	22
Texas	34	12	25	30									78	28	21	27	630	23	77	56				3	116	315	284
Tennessee	204	11	19	28	2	12	4	7					77	21	6	13	1,910	24	33	34	44	7	69	2	189	23	31
Mississippi													37	18	5	6	880	18	28	28				7	296	100	119
Alabama	19	11	3	2									71	18	8	11	860	15	31	32				7	188	110	123
Georgia	44	10	5	13	3	9	7	10					74	18	10	17	890	14	40	41				7	188	150	140
Arkansas	31	12	4	6									67	24	5	12	910	21	25	26				4	188	69	74
North Carolina	108	10	13	14	4	9	7	39					63	17	5	13	910	17	28	30	95	5	175	3	208	44	53
South Carolina	89	10	9	6	1	10	2	2					121	21	6	9	870	16	21	23	13	7	24	8	215	78	95
Florida													73	16	1	1	120	12	6	6	2	7	2	2	112	8	6
Louisiana													10	20	1	1	630	22	22	18				4	162	30	51
		11	110	122		11	22	48		25	4			21	85	110		18	362	303		7	270		175	995	997
(iii) The Northeastern States.																											
New York	164	20	9	9	65	17	85	133	42	26	11	59	775	31	38	59	430	35	6	6	8	11	5				
Connecticut					42	19	5	9					68	32			430	42	1	1	215	15	11				
Vermont	3	24			4	16	1	1	46	31	2	6	290	36	2	4	230	33	1	1							
New Hampshire									5	25		2	45	35		1	110	38									
Rhode Island													51	30			320	36									
Massachusetts					11	17	2	5					29	31			210	40	1		43	15	4				
Maine	6	26							19	30	1	4	133	37	4	5	16	40									
		23	9	9		17	93	148		28	14	71		34	44	69		38	9	8		11	20				
(iv) The Central Eastern States.																											
Pennsylvania	645	18	32	35	144	17	190	182	5	25	1	3	650	29	28	45	1,170	37	14	16	38	12	27				
New Jersey	256	18	2	3	204	17	43	40					226	30	2	3	1,260	35	3	3							
Maryland	1,300	17	16	18	34	15	10	16	3	31			78	27	1	3	2,240	34	6	7	80	6	25				
Delaware	1,000	17	2	2	8	15							55	28			2,860	30	2	2							
West Virginia	190	13	8	11	6	13	6						78	21	3	5	1,190	20	8	8	7	7	16				
Virginia	21	12	16	19	7	13	10	22	1	29			77	20	5	13	1,140	25	19	21	98	7	130				
		16	76	88		15	259	260		28	1	3		26	39	69		32	52	57		8	196				
(v) The West Coast States.																											
Washington	42	19	30	25	2	21	3	1	86	33	26	14	120	45	6	3	5	27									
Oregon	151	21	15	28	2	17	7	4	22	31	9	11	98	35	9	7	4	28									
California	122	16	19	66	8	14	29	24	196	27	193	307	34	34	6	3	11	35									
		19	64	119		17	39	29		30	228	332		38	21	12		30									
(vi) The Mountain States.																											
Nevada	9	29	1	1					2	36	1		2	43													
Utah	60	25	5	4	1	18	1	2	6	40	2	2	26	46	2	1	4	30									
Colorado	71	24	8	7	1	17	2	1	5	36	4	4	53	39	6	4	26	21	1	1							
Arizona	3	25							7	38	5		1	38			2	33									
Idaho	107	26	11	4	1	20	2		24	38	9	4	61	42	5	1	2	30									
New Mexico	9	23	1	4									4	33	1		11	27									
		25	25	20		18	5	3		38	21	10		40	14	6		28	1	1							
Grand total		17	993	998		16	987	983		30	1,000	994		29	1,004	973		29	1,001	994		9	990		175	995	997

(*a*) Crop in bushels per square mile of total area of State.
(*b*) Yield in bushels per acre.
(*c*) Fraction of U. S. A. area devoted to the crop in 1910 (per mile).
(*d*) Fraction of U. S. A. area devoted to the crop in 1900 (per mile).
(*e*) Crop in tons per square mile of total area of State.
(*f*) Yield in hundredweight per acre.
(*g*) Yield in pounds per acre.

umns under any crop may be regarded as a very good grower of that crop.

Each crop may now be considered in detail; in each case the best States will be compared with an equal number of moderate States.

WHEAT.

Best six States: Indiana, North Dakota, Kansas, Ohio, Minnesota, Illinois.

Moderate six States: Virginia, New York, Wisconsin, Michigan, Tennessee, Georgia.

	Best States.	Moderate States.
Winter wheat, growing periods (months)	9½–10½	7⅔–10½
Winter wheat, rainfall (inches)	22– 32	22– 31
Spring wheat, growing periods (months)	3⅔– 4½	3½– 3⅔
Spring wheat, rainfall (inches)	10– 15	10– 13

It thus appears that winter wheat requires a rainfall of from 22 to 32 inches during a growing period of 10 months, and in this connection it may be noted that the Cotton States obtain this quantity of rain during a shorter growing period and that they also obtain a low yield per acre and have as a whole a declining acreage.

Spring wheat requires about four months and a rainfall of about 13 to 15 inches; the 10 inches in the Summary (p. 270) above is solely due to North Dakota, where the yield per acre is, on the average, low. The moderate States lack both time and rainfall, and the Cotton States, where spring wheat is not usually grown, have too much rainfall during the summer months.

RYE.

Best three States: Pennsylvania, Michigan, Wisconsin.

Moderate three States: Virginia, Nebraska, Illinois.

	Best States.	Moderate States.
Rye, growing periods (months)	9⅔–10½	9½–10
Rye, rainfall (inches)	24– 30	20–32

Winter rye requires about 27 inches of rain during 10 months. The Cotton States have a low yield, a short growing period, too much or too little rain, and a declining acreage. Minnesota and Kansas are States of small relative acreage which have too little rain.

BARLEY (SPRING-SOWN).

Best three States: South Dakota, Minnesota, Wisconsin.

Moderate three States: Kansas, Nebraska, Michigan.

	Best States.	Moderate States.
Spring barley, growing periods (months)	2⅔–3½	3–3½
Spring barley, rainfall (inches)	9 –11	10–12

Spring barley is best suited by about 3 months' growth and 10 inches of rainfall. North Dakota suffers from a poor yield with deficient rainfall and a short period; New York has too much rain. The Cotton States and those of the neighboring central-eastern area have too much rain during the three suitable summer months.

The deficient acreage under barley in Indiana, Ohio, and Kentucky may be associated with an excess of rainfall for spring-sown barley and an apparent failure to grow fall-sown barley successfully.

OATS.

Best four States: Iowa, Illinois, Indiana, Wisconsin.

Moderate States: Michigan, South Dakota, Minnesota, New York.

	Best States.	Moderate States.
Oats, growing periods (months)	3½– 4	3⅔– 4
Oats, rainfall (inches)	13–15	11–14

Oats are suited by about 14 inches of rain during a growing period of about 3⅔ months. The Cotton States contain about one-twelfth of the total oats acreage, have a small yield per acre and an excessive rainfall and growing period. Kentucky, Missouri, and North Dakota fail comparatively as producers of oats since they fail to provide the suitable conditions of rainfall.

MAIZE.

Best three States: Iowa, Illinois, Indiana.

Moderate three States: Nebraska, Kansas, Kentucky.

	Best States.	Moderate States.
Maize, growing periods (months)	4⅓–5½	4⅓– 6
Maize, rainfall (inches)	17–18	17–20

Maize flourishes with about 18 inches of rainfall during a growing period of about five months. Minnesota, South Dakota, and Wisconsin receive too little rain and the Cotton States[3] receive too much. It has been noted that the growing period of maize in the Cotton States is very prolonged, and this should be associated with the very poor yield per acre which is obtained.

TOBACCO.

Best three States: Kentucky, North Carolina, Virginia.

Moderate three States: Ohio, Tennessee, Pennsylvania.

	Best States.	Moderate States.
Tobacco, growing periods (months)	3½	2½– 3½
Tobacco, rainfall (inches)	13–15	10 –13

Tobacco apparently requires about 14 inches of rain during a growing period of about three months near to midsummer. The majority of the States in the central and northeastern areas lack rainfall; Connecticut forms the striking exception.

[3] Under the better cultivation given by the boys who compete for the "corn prizes" offered by U. S. Department of Agriculture the "Cotton States" have given *the highest yield of corn* (maize) *per acre* in U. S.—EDITOR.

COTTON.

Best three States: Georgia, Alabama, Mississippi.

Moderate three States: Texas, South Carolina, Tennessee.

	Best States.	Moderate States.
Cotton, growing periods (months)	4⅔	4½- 5
Cotton, rainfall (inches)	19-21	17 -19

Cotton is suited best by about 20 inches of rain during a growing period of 4⅔ months. No States outside the cotton belt can provide these conditions during the hottest months.

Sections A and B (north) are best suited to spring wheat; section A reaches the standard as regards spring barley and contains a progressive acreage which increased by about one third during the decade, 1901–1910. Sections F and B (north) are good for oats. Section B (north) approaches the standard for maize. The tobacco belt occurs in sections H and L, and the cotton belt includes rainfall sections B (south), H, and L.

Reference to the typical graphs shown on the map [4] makes it clear that successful crop growing does not tend to be limited to one type of rainfall per crop, and this diversity of association between crop and rainfall emphasizes the conclusions already attained, that the successful agriculturist arranges his growing season to suit the rainfall conditions which prevail in his neighborhood.

TABLE 4.—*Summary of Table 3 by rainfall sections.*

Sections. (See fig. 43.)	Wheat.			Rye.			Barley.			Oats.			Maize.			Tobacco.		Cotton.		
	Bu./A.	(c)	(d)	*Bu./A.*	(c)	(d)	*Bu./A.*	(c)	(d)	*Bu./A.*	(c)	(d)	*Bu./A.*	(c)	(d)	*Cwt./A.*	(c)	*Lbs./A.*	(c)	(d)
A	17	501	441	17	153	225	23	595	466	29	432	342	27	267	320					
B, north	16	83	86	16	192	172	28	123	89	30	218	232	32	180	177	9	25			
B, south	13	57	53	14	2		25	4		28	38	27	20	128	62			140	383	306
C; part of D	19	64	119	17	39	29	30	228	332	38	21	12	30							
F	20	27	38	17	266	193	27	22	80	32	83	98	35	27	21	14	20			
G	18	92	62	17	45	39	26	5	10	31	103	89	37	80	83	8	97			
H	12	46	71	12	17	31				21	39	75	24	189	196	7	451	192	452	487
K	18	52	58	16	243	238	28	1	3	28	31	51	34	25	28	9	50			
L	12	46	50	12	25	53				20	19	40	22	76	82	7	345	212	122	147
M										16	1	1	12	6	6	7	2	112	8	6
N										20	1	1	22	22	18			162	30	51
P; parts of D and E	25	25	20	18	5	3	38	22	14	39	18	11	28	1	1					
	17	993	998	16	987	983	30	1,000	994	29	1,004	979	29	1,001	994	9	990	175	995	997

(c) Area of the United States in the crop in 1910 (thousandths).

(d) Area of the United States in the crop in 1900 (thousandths).

TABLE 5.—*Summary of Table 2 by rainfall regions.*

Sections.	Winter crops.				Spring crops.											
	Wheat.		Rye.		Wheat.		Barley.		Oats.		Maize.		Tobacco.		Cotton.	
	Growing period.	Rainfall during growth.	Growing period.	Rainfall during growth.	Growing period.	Rainfall during growth.	Growing period.	Rainfall during growth.	Growing period.	Rainfall during growth.	Growing period.	Rainfall during growth.	Growing period.	Rainfall during growth.	Growing period.	Rainfall during growth.
	Mos.	*Inches.*	*Mos.*	*Inches.*	*Mos.*	*Inches.*	*Mos.*	*Inches.*	*Mos.*	*Inches.*	*Mos.*	*Inches.*	*Mos.*	*Inches.*	*Mos.*	*Inches.*
A	10	19	10	21	3⅔	13	3	10	3½	12	4⅓	15				
B, north	9⅔	26	9⅔	26	3⅔	14	3½	13	3⅔	13	4⅓	18	2⅔	11		
B, south	8⅔	21	9	22	4⅓	11	4	12	4⅓	15	6	20			5	18
C	10⅔	31														
F	10⅔	31	10½	33	3½	11	2⅔	10	3⅓	12	4	14	2	8		
G	9⅔	30	10	31			3⅔	14	4	15	4⅓	17	3	11		
H	8⅓	30	9	35					4	19	6	25	3½	13	4⅓	19
K	8⅓	31	9	31	3½	13	3⅔	14	3⅓	14	4½	18	2⅔	11		
L	8⅔	31	9	32	4⅓	20			3⅔	15	5½	23	3½	15	4⅓	19
Average of above values	9½	28	9½	29	4	14	3⅔	12	4	14	5	19	3	12	4⅓	19
Standard value	10	27	10	27	4	14	3	10	3⅔	14	5	18	3	14	4⅓	20

Relation between rainfall regions and crops.

In a broad way Tables 4 and 5 summarize Tables 3 and 2 respectively. The average values calculated in Table 5 confirm the standard values obtained by a different method—that of sampling—in the preceding section.

No rainfall section appears to provide the best conditions for winter wheat; section B (north) approximates most closely, and this region has progressed in acreage under winter wheat at the same rate as the whole country. Winter rye appears to succeed best in rainfall sections F and G; the lack of rain militates against section A.

Conclusion.

The methods adopted in this paper are almost entirely based upon average values, and hence the general conclusions are valid only in a broad way. It might be expected that the averages would eventually yield complete symmetry and agreement between the results; the fact that such symmetry is not found is important testimony for the validity of the conclusion enunciated at the end of the preceding section.

Attention has been concentrated upon rainfall for the definite purpose of determining the importance of the

[4] These graphs were omitted from figure 43 to avoid crowding; they presented the sectional rainfall marches detailed in this REVIEW, April, 1915, p. 177.

rainfall factor in the complex conditions of the environment of the agriculturist. In itself the rainfall regime of an area is typical of its latitude, its situation both on the continent and in relation to the ocean. Therefore, a close relationship between successful agriculture and definite rainfall conditions might have been assumed. It is the purpose of this inquiry to have laid bare, first, the validity of such an assumption, and secondly, the details regarding the relationship. It may be hoped that, in so far as agricultural progress results from purposeful guidance from without, the conclusions herein attained may serve as an indication of directions in which such progress may be most rapidly and easily achieved.

A REVOLVING CLOUD CAMERA.

By OLIVER L. FASSIG.

[Dated: Weather Bureau, Baltimore, Md., July 12, 1915.]

About 10 years ago a new form of camera was brought to my attention by its designer, Mr. Fred. W. Mueller, of Baltimore, with the hope that such a device might prove to be of value to meteorologists. The camera revolved upon a vertical axis by means of a spring motor, a complete revolution being made in from 5 to 10 seconds, depending upon the illumination. The image was thrown upon a film, which automatically unrolled as the camera revolved. By this means a picture was secured of the entire horizon of 360° and of the lower portions of the sky, projected upon a long and narrow sheet of paper. The device produced some very interesting and striking effects when applied to landscape photography, but where large angular sections were involved the relative positions of objects in the field of view were obviously much disturbed.

While this new camera was of general interest to me, I suggested to Mr. Mueller that a modification of his device, in order to make it possible to secure, by means of a single exposure, a complete picture of the sky from horizon to zenith and through 360° of azimuth, might prove to be of considerable value in the study of the forms and the distribution of clouds. The work of designing and constructing a suitable camera for this specific purpose was at once undertaken with enthusiasm by Mr. Mueller. Four or five years later official assignment to another field took me away from Baltimore before a camera was perfected which entirely satisfied the inventor. Upon my return to Baltimore, in the summer of 1912, one of the first visitors to call at the local office of the Weather Bureau was Mr. Mueller, bringing with him a new camera, designed and constructed by him, together with some excellent cloud photographs.

An examination of the camera and the preliminary photographs convinced me that a satisfactory method had been found for photographing, by means of a single exposure, the entire arch of the sky and all visible objects therein. The accompanying photographs, shown in figures 1 to 3, give a good idea of the general appearance and construction of the camera, while the sectional drawing, figure 4, shows how the rays of light from the various points of the sky pass through the lens and reach their proper positions on the sensitized plate or film, *bd*, within the camera.

The heavens as seen from any particular point appear to the observer as a dome, and it occurred to Mr. Mueller that to photograph the sky upon a circular plate would give a fairly true rendering of the relative positions of all objects in the sky at the time of the exposure. The photograph of the sky secured with this particular instrument is 12 inches in diameter (fig. 5), the zenith is in the center of the picture, and the horizon along the circumference. The exposure of the sensitized plate or film is accomplished in one uninterrupted operation through a wedge-shaped opening in the plate-holder cover while the plate in its holder revolves around its own axis, and the entire camera revolves around a vertical (zenithal) axis, in turn facing every point of the horizon.

The wedge-shaped opening in the plate-holder cover is about a quarter of an inch wide at the circumference of the plate and tapers to a point at the center. The vertical angle included during exposure, as the camera revolves, is 90° or from the horizon to the zenith. It will be seen, then, that, as the camera makes a complete revolution, it will include 180°, or the entire visible dome of the sky.

The body of the camera is so mounted that the plate makes an angle of 45° with the plane of the horizon and with the line to zenith. The upper segment of the revolving plate is exposed, the light from the zenith passing down vertically through the lens and striking the center of the plate, while the rays from the horizon reach the edge of the plate. (See fig. 4.)

As the camera revolves and the plate moves past the wedge-shaped opening in the plate-holder cover fresh segments of the sensitized plate are successively presented to the sky until the entire exposure is made, when the shutter automatically closes, just as it automatically opened at the beginning of the exposure.

An important feature of the instrument is the automatic shutter. The plate is contained in a circular holder, upon the cover of which is the shutter. When an exposure is to be made the cover is raised away from the plate holder—by means of the screws seen on the outside of the camera in figures 1 and 2—which then becomes a fixed part of the camera cover. This operation brings the shutter beneath the lens and at the same time automatically sets it for action.

As the plate holder revolves around its own axis the camera revolves about a vertical axis, retaining its upright position, with the lens and shutter at the top. This is effected by guides which operate in a groove around the pedestal head. The relative rate of rotation of the camera and the plate is governed by the size of the large gears connecting them, shown in figure 3. The spring motor, by means of which the camera makes a complete revolution in from 5 to 10 seconds, is shown in position in figures 2 and 3. The lens subtends an angle of 90°, has a focal length of 3 inches, and is adjusted for objects at infinite distance.

The negative produced by means of the camera requires a certain correction in order to produce a picture of the sky which shall present all objects photographed in their true relations. The axis of revolution of the plate (*dba* in fig. 4) is at an angle of 45° to the axis of revolution of the camera. The lens is fixed at the center of the upper portion of the face of the camera. Hence, as the camera revolves, the image of the sky is apparently thrown upon the interior surface of an inverted cone. (See fig. 4, *abc*.) The apex of this cone, corresponding to the zenith, is at the center of the sensitized plate (fig. 5, *Z*), while the edge of the base, which limits the rays from the horizon, corresponds to the circumference of the plate. The sides of the cone subtend an angle of 90° and are equal in length to the semidiameter of the plate. The actual image is projected upon a revolving plane surface (the plate) which is tangent to the surface of the imaginary cone. The ratio of the area of the cone to the area of the circular plate is the same as the ratio of the base to the hypotenuse of a right triangle. Hence there